CHAPTER 4 IDENTIFICATION OF BENEFICIAL USE IMPAIRMENT ASSESSMENTS

4.1 Summary

This chapter provides status reports for each of 14 Beneficial Use Impairments (BUI) identified in the Great Lakes Water Quality Agreement (1987) including a brief account of the LaMP's original determination of their status. Some of this material was taken from the 1998 LaMP Stage 1 report and updated using various sources of information as shown in the references. In 2005, the status of the Degradation of Fish Populations BUI was reviewed as recent data and scientific interpretation clearly showed the offshore to be impaired. No previously impaired beneficial uses have changed status. The Zooplankton component of the Phytoplankton and Zooplankton BUI is currently under review and no recommendation for change was made at the time this chapter was revised.

The information contained in this chapter has been compiled based on documents produced up to March 31, 2005 for sections 4.4, 4.5, and 4.6. All others are virtually identical to that printed in LaMP Status Report April 2004. Information on current environmental conditions and issues is provided in Chapter 3, Ecosystem Indicators.

4.2 Beneficial Use Impairments Defined by the Great Lakes Water Quality Agreement

Significant changes have occurred in the Great Lakes over the last century due to the effects of toxic pollution, changes in nutrient input, fishing, and habitat loss resulting from water level regulation, power generation, rapid agricultural, industrial, and urban development within the Great Lakes watersheds and also by accidental and intentional introductions of non-native species. In 1972, Canada and the United States took actions to ban and control contaminants entering the Great Lakes, and, in 1987, renewed the Great Lakes Water Quality Agreement (GLWQA) with the goal to restore and maintain the chemical, physical, and biological integrity of the Great Lakes ecosystem.

The GLWQA (1987) provides fourteen indicators of beneficial use impairments (identified in the text box below) to help assess the impact of chemical, biological and physical factors on the Great Lakes ecosystem. These indicators provide a systematic way to identify impacts on the entire ecosystem, ranging from phytoplankton to birds of prey and mammals, including humans.

These impairments reflect those beneficial uses of the Great Lakes which cannot presently be realized because the physical, chemical, and/or biological integrity of the ecosystem has been compromised. These impairments are continuously evaluated on the other Great Lakes and in Areas of Concern (AOC). Given the rapid environmental changes that have occurred over the last 20 years, emphasis was placed on using the most recent information available at the time to identify problems facing the Lake Ontario ecosystem. Local impairments found in Lake Ontario AOCs and other nearshore areas are also discussed.

4.3 Beneficial Use Impairment Identification Process and Problem Definition

In preparing the Stage I binational problem assessment, Canada and the United States first independently evaluated 13 of the Lake Ontario beneficial use impairments for those geographic areas within their jurisdictions (Rang et al., 1992; USEPA and NYSDEC, 1994). The agencies proceeded to integrate their separate evaluations into the binational assessment of the status of beneficial use impairments in Lake Ontario. The fourteenth beneficial use impairment, loss of fish and wildlife habitat, was evaluated using Lake Ontario habitat reports compiled by the United States Fish & Wildlife Service (USF&WS) as part of the LaMP evaluation process (Busch et al., 1993) and others (Whillans et al., 1992). The LaMP recognizes the importance of appropriate linkages to other natural resource management initiatives such as the Great Lakes Fishery Commissions Fish Community Goals and Objectives, provincial and state fishery management plans, International Joint Commission's lake-level management plan, wetlands protection, watershed management plans, and control strategies for exotic species.

The Great Lakes Water Quality Agreement definition of "impairment of beneficial use(s)" is a change in the chemical, physical, or biological integrity of the Great Lakes System sufficient to cause any of the following:

1. Restrictions on fish and wildlife consumption
2. Tainting of fish and wildlife flavor
3. Degradation of fish and wildlife populations
4. Fish tumors or other deformities
5. Bird or animal deformities or reproductive problems
6. Degradation of benthos
7. Restrictions on dredging activities
8. Eutrophication or undesirable algae
9. Restrictions on drinking water consumption, or taste and odor problems
10. Closing of beaches
11. Degradation of aesthetics
12. Added costs to agriculture or industry
13. Degradation of phytoplankton and zooplankton populations
14. Loss of fish and wildlife habitat

4.4 Beneficial Use Impairments in Lake Ontario

In the 1800s and early 1900s, much of Lake Ontario's watershed was deforested, its tributaries were dammed, and non-native species were introduced both purposely and accidentally. In the 1900s, rapid development of the Lake Ontario basin was accompanied by further habitat loss, unregulated harvest of fish, and the release of excessive nutrients and toxic pollution that caused major changes in the Lake Ontario ecosystem. Also during this time, sea lamprey became very abundant adding to the declines in native species like lake trout. From 1900 to 1960, Atlantic salmon, deep water ciscoes, deep water sculpin and lake trout were extirpated as a result of many or all of the above reasons. By the 1960s and 1970s, Lake Ontario's near shore waters were choked with algae and colonial water birds experienced nearly total reproductive failure due to the presence of high levels of toxic contaminants in the food chain. Similarly, near shore production of several species of fish including walleye and lake whitefish also declined significantly, allowing populations of non-native species like white perch and alewife to increase dramatically.

The reduction of contaminant and phosphorus loadings beginning in 1972 resulted in a major turn of ecological events in Lake Ontario most of which seemed to provide a promising positive outlook. The 1987 revision of the GLWQA focused on remediation, restoration and maintenance of the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem and provided a set of impairments by which to evaluate the state of the lake.

Today, as a result of these actions, levels of toxic contaminants in the Lake Ontario ecosystem have decreased significantly. Colonial waterbird populations have recovered and are reproducing normally. However, bioaccumulative toxics persist in sediment, water and biota at levels of concern for higher order predators (such as bald eagles, snapping turtles, mink, otters and humans).

Polychlorinated biphenyls (PCBs), DDT, mirex, dieldrin, mercury and dioxins/furans have been identified as critical pollutants linked to lakewide impairments in Lake Ontario. In addition to the historical loss of significant habitats, artificial lake level controls were identified as a significant cause of degraded habitats. (Refer to the 1998 “Lakewide Management Plan for Lake Ontario - Stage 1 Report” for a detailed discussion on the evaluation of these lakewide impairments.) Although there have been positive changes related to these impairments, their overall status of “impaired” remains unchanged.

The following is a summary of the technical basis for the beneficial use impairment assessment and the identification of the chemical, physical, and biological factors contributing to these impairments. A general list of references is provided in Section 4.7. Detailed references for information sources are provided in the individual United States and Canadian assessment reports that were used for this evaluation. In the development of the LaMP, the lakewide impairment status (impaired, degraded, insufficient information, or unimpaired) was determined after consideration of the Ecosystem Goals for Lake Ontario (see Section 3.2.1) and the preliminary ecosystem objectives.

Since the LaMP 1998 report, 7 lakewide beneficial use impairments related to persistent toxic substances, food web disruption from non-native species and habitat degradation/loss have been identified:

1. restrictions on fish and wildlife consumption;
2. degradation of wildlife populations;
3. bird or animal deformities or reproductive problems; and
4. loss of fish and wildlife habitat.
5. degradation of benthos; and
6. degradation of nearshore phytoplankton populations
7. degradation of fish populations (primarily off shore).

The factors responsible for these impairments are identified in Table 4.1. PCBs, DDT, dioxins, and mirex are the critical pollutants associated with one or more of these lakewide impairments. Loss of fish and wildlife habitat is due primarily to physical and biological factors rather than toxic contaminants. The LaMP Management Committee and Working Group reviewed the status of degradation of fish populations BUI and changed it to impaired in 2005. The primary reasons were impacts of non-native species on the off shore food web and not meeting ecological objectives as stated in Chapter 3 for lake trout and prey fishes. The status of zooplankton remains unchanged but is currently under review.
The Lake Ontario AOCs, with the exception of the Port Hope AOC, also list some or all of these impairments as local concerns. The St. Lawrence River AOC shows only fish and wildlife consumption restrictions as impaired at this time. The LaMP process will be coordinated with the continuing activities of the local Remedial Action Plan councils to ensure the development of effective strategies for lakewide critical pollutants and other lakewide issues. The LaMP process will also support and provide integration of other existing programs that address these lakewide issues.

4.4.1 Restrictions on Fish and Wildlife Consumption

The LaMP Management Committee agreed that fish and wildlife consumption advisories due to PCBs, dioxins and furans, and mirex made this beneficial use impaired lakewide. Most human exposure to many persistent and bioaccumulative contaminants is through eating fish and other aquatic organisms, which far outweighs contaminant exposures related to drinking water, air, or other terrestrial sources. Consumption advisories are developed to help protect people from the potential health impacts associated with long term consumption of contaminated fish and wildlife.

Table 4.1 Lake Ontario Lakewide Beneficial Use Impairments, Impacted Species and Causes

Lakewide Impairments	Impacted Species	Lakewide Critical Pollutants and Other Factors
Restrictions on Fish and Wildlife Consumption	Trout, Salmon, Channel catfish, American eel, Carp, White sucker Walleye[1], Smallmouth bass[1] All Waterfowl[2] Snapping Turtles[2]	PCBs, dioxins, mirex, Mercury PCBs, dioxin and Mirex PCBs
Degradation of Wildlife Populations	Bald Eagle[3] Mink and Otter[3]	PCB, dioxin, and DDT PCBs
Bird or Animal Deformities or Reproductive Problems	Bald Eagle[3] Mink and Otter[3]	PCB, dioxin, and DDT PCBs
Loss of Fish and Wildlife Habitat	A wide range of native fish and wildlife species	Lake level management Non-native species Physical loss, modification and destruction of habitat
Degradation of Benthos	*Diporeia hoyi* populations	Non-native species and unknown causes prior to introduction of zebra mussels
Degradation of Phytoplankton Populations	Nearshore phytoplankton	Non-native species and other factors to be confirmed
Degradation of Fish Populations	Lake trout Prey fishes Lake whitefish	Poor survival of eggs and young lake trout caused by predation and early mortality syndrome as well as continued exploitation of adult fish Imbalanced predator prey ratios in food web, poor survival or reproduction of non-native prey base, very low abundance of native prey fishes, low prey fish diversity, and nutritional factors Loss of *Diporeia hoyi*, nutritional factors, fishing

1. Canadian advisories only.
2. U.S. advisories only
3. Indirect evidence only (fish tissue contaminant levels)

Notes: The term "DDT" includes all DDT metabolites. The term "dioxin" includes furans. Dieldrin, although identified as a critical pollutant, is not linked to a beneficial use impairment.

For New York State Guidelines www.health.state.ny.us and Ontario Ministry of Environment Guidelines www.ene.gov.on.ca .

Fish Consumption Advisories

In general, consumption advisories are based on contaminant levels in different species and ages of fish. Both Ontario and New York fish consumption advisories account for the fact that contaminant levels are generally higher in older, larger fish. There are some differences in the fish tissue monitoring processes of the two governments; for example, New York State analyzes entire fillets which include belly-flap and skin (catfish, bullhead, and eels are exceptions since skin is removed before analysis) and Ontario analyzes muscle fillets. These two types of fish samples are not directly comparable. Muscle fillets have lower fat content. Since organochlorine chemicals, such as PCBs and DDT, tend to concentrate in fatty tissue, muscle fillet samples will generally show lower levels of these contaminants than the levels found in the fattier fillets.

Although not responsible for consumption advisories on a lakewide basis, mercury in larger smallmouth bass and walleye was considered likely to exceed Ontario's 0.5 ppm criteria for human consumption and was therefore considered a factor in listing this beneficial use as impaired (Table 4.1).

In Ontario, a Sports Fish Contaminant Monitoring Program is administered by the Ontario Ministry of the Environment (OMOE) and the Ontario Ministry of Natural Resources (OMNR). New York State operates a statewide fish tissue monitoring program. USEPA's Great Lakes National Program Office coordinates a fish tissue monitoring effort as part of a long term contaminant trends monitoring project. Fish tissue samples are also collected by the Canadian Food Inspection Agency (CFIA) term contaminant trends monitoring program.

In Ontario, sportfish advisories are published every two years in the Guide to Eating Ontario Sport Fish, which includes tables for the Great Lakes. Various consumption advisories were reported for 19 species: salmon (Chinook, Coho), trout (rainbow, brown, lake), white bass, yellow and white perch, whitefish, rainbow smelt, freshwater drum, channel catfish, white and redhorse suckers, brown bullhead, American eel, black crappie, gizzard shad, and carp. The contaminants responsible for advisories are PCBs (61%), dioxins and furans (32%), and mercury (7%). The regular evaluation of commercial catches by the CFIAs fish inspection program has led to some restrictions on the commercial harvest of bowfin, lake trout, carp, large walleye, and channel catfish. In 2005, OMOE published new guidelines that use a new tolerable daily intake approach to assessing risk from contaminants in sport fish.

The New York State Department of Health issues annual fish consumption advisories for New York State waters which include specific and general advisories for Lake Ontario. NYSDEC collects and analyzes fish for contaminants. "Eat none" advisories are in place for Lake Ontario American eel, channel catfish, carp, and lake trout >25", Chinook salmon, brown trout over 20 inches, and white perch (west of Point Breeze). "Eat no more than one meal per month" advisories are in effect for Lake Ontario white sucker, Coho salmon over 25 inches, brown trout less than 20", smaller lake trout, rainbow trout, and white perch (east of Point Breeze). "Eat no more than one meal per week" advisories are in effect for many Lake Ontario fish species not listed above. In addition, an "Eat none" advisory, which applies to all Lake Ontario fish, is in effect for all women of childbearing age and children under the age of 15. This stringent advisory is designed to protect these sensitive human populations from any increased exposure to toxic contaminants.

In addition to these lakewide consumption advisories caused by organic contaminants, it is worth noting that a considerable number of local advisories have existed in Canadian waters due to mercury. Mercury advisories were reported for nine species of fish, including walleye, in fourteen locations. Walleye is an important recreational fishery in the eastern end of Lake Ontario. Fish consumption advisories are periodically reconsidered if new information suggests that more restrictive advisories are necessary to fully protect human health or if contaminant levels have dropped below guidelines.

The effect of any one or all contaminants on the fish species described is discussed in the degradation of fish and wildlife section.

Wildlife Consumption Advisories

Diving ducks, such as mergansers, feed on fish and other aquatic organisms and, as a result, tend to be the most heavily contaminated waterfowl. New York has a statewide advisory recommending that mergansers not be eaten and that the consumption of other types of waterfowl be limited to no more than two meals per month. The New York State Health Department also advises that wild waterfowl skin and fat should be removed before cooking and that stuffing be discarded. The contaminants of concern for Lake Ontario mergansers in New York are PCBs, DDT, and mirex.

Snapping turtles are another example of a high level predator that is near the top of the food chain. Over their relatively long life span, snapping turtles can accumulate significant levels of persistent toxic substances in their fatty tissues. New York's statewide advisory recommends that women of childbearing age, and children under the age of 15, "eat no" snapping turtles, and recommends that others who choose to consume snapping turtles should reduce their exposure by trimming away all fat and discarding the fat, liver, and eggs prior to cooking the meat or preparing the soup. This advisory is based on PCBs, as the primary contaminants of concern.

Studies conducted by the Canadian Wildlife Service of Environment Canada have shown contaminant levels in ducks to be below guidelines. Snapping turtle eggs from a number of locations in Lake Ontario exceed the PCB minimum consumption guidelines for sport fish. Although there has been no direct assessment of turtle muscle, turtle muscle with all fat removed would likely be below consumption guidelines. There are no consumption advisories for wildlife species in the Canadian portion of the Lake Ontario basin.

4.4.2 "Degradation of Wildlife Populations" and "Bird or Animal Deformities or Reproduction Problems"

The two impairments, "degradation of wildlife populations" and "bird or animal deformities or reproduction problems," are addressed together in this section since past declines in some wildlife populations have been directly related to contaminant-related reproduction problems. Wildlife population and reproduction impairments are lakewide impairments caused by PCBs, dioxin equivalents, and DDT. Wildlife used in the evaluation of this beneficial use indicator included mink, otter, bald eagles, and colonial water birds. These species were chosen because of historical, documented problems associated with contaminants or other non-chemical stressors. These species are useful indicators of environmental conditions because of their high level of risk due to being at or near the top of the food chain or requiring special habitat in order to reproduce successfully.

At the time of the BUI determination, there was indirect evidence that bald eagle, mink, and otter populations remained degraded along the Lake Ontario shoreline. Levels of PCBs, dioxins, and DDT and its metabolites in the food chain were thought to be important factors limiting the recoveries of these wildlife populations. There was no indication at that time that existing levels of contaminants in the open waters were degrading fish populations.

Bald Eagles

Bald eagle populations began to decline in the early 1900s due to hunting and loss of habitat. In the decades following the introduction of DDT in 1946, contaminant-induced eggshell thinning lowered reproductive success throughout North America, including the Lake Ontario basin. During the 1980s, after DDT and other pesticides were banned, two successful bald eagle nesting territories were reestablished in the Lake Ontario basin using adult eagles captured in Alaska. By 1995, bald eagles had recovered to the point that they were moved from the U.S. endangered species list to the threatened species list. They retain their endangered status in Ontario.

In 1995 there were at least six successful bald eagle nesting territories in the Lake Ontario basin which have fledged more than sixty eaglets since 1980 (Nye, 1979, 1992). Since then the number of nesting territories has steadily increased in the basin and each territory has fledged on average one or more eaglets per nest. Chapter 3 provides details on the most recent information on the numbers of bald eagle nesting territories and eaglets successfully fledged.

In 1992, a survey of the entire Lake Ontario shoreline (both Canadian and U.S. sides) for suitable breeding habitat for bald eagles was conducted by Environment Canada, the Ontario Ministry of Natural Resources, and U.S. bald eagle experts. A more quantitative GIS study was completed throughout the basin in 2005, involving USEPA, NYSDEC, Environment Canada, Ontario Ministry of Natural Resources and Bird Studies Canada, with the objectives of identifying and ultimately protecting prime bald eagle nesting habitat over the next 10 years.

There was indirect evidence that bald eagle reproduction in the Lake Ontario basin was impacted by persistent toxic contaminants. Studies of bald eagles nesting on other Great Lakes shorelines in the 1980s suggested that levels of PCBs, dioxins, and DDT in the Lake Ontario food web may have caused lowered reproductive success, increased eaglet deformities, and early adult mortality (Best, 1992; Bowerman et al., 1991). Bald eagles as fish consumers, as well as scavengers of bird carcasses on islands and shorelines, may be at risk from direct and secondary exposure to botulism (see Chapter 10); however, at this time botulism has not been identified as the cause for the death of any bald eagles.

Colonial Waterbirds

Colonial waterbirds have a long history of being used as indicators of contaminant effects and ecosystem health on Lake Ontario and throughout the Great Lakes (Gilbertson, 1974; Mineau et al., 1984). In the 1970s, Gilbertson (1974, 1975) and Postupalsky (1978) found highly elevated contaminant levels in eggs, severe eggshell thinning, elevated embryonic mortality, high rates of deformities, declining population levels, and total reproductive failure among several species of colonial waterbirds on Lake Ontario. Many of these conditions had improved substantially at the time of the BUI determination, [e.g., concentrations of PCBs, dieldrin, total DDT, mirex, mercury, and dioxins had declined significantly in herring gull eggs and, to a lesser extent, in cormorants and common and Caspian terns (Weseloh et al., 1979, 1989; Ewins and Weseloh, 1994; Bishop et al., 1992; Pettit et al., 1994). Additionally, eggshell thickness had returned to normal (Price and Weseloh, 1986; Ewins and Weseloh, 1994), and population levels had increased (Price and Weseloh, 1986; Blokpoel and Tessier, 1996)]. The status of some of these conditions was unknown at that time and some new issues had arisen (physiological biomarkers, endocrine disruption, structural deformities) in birds as well as other classes of wildlife (G.A. Fox, Canadian Wildlife Service personal communication)

Since the assessment of the BUI, Weseloh et al. (2003) have shown that contaminant levels in herring gull eggs continued to decline and for all of the contaminants monitored since the beginning of the project levels had declined between 89 and 98% by 2000. In reference to a wide variety of colonial waterbirds, notable gulls, terns, egrets and cormorants, they concluded “Contaminant induced biological effects do not appear to be limiting factors at the population level.” This conclusion was based on the number of fledglings produced, colony size, and number of colonies. Yet to be addressed, however, are issues of recruitment, survival, or duration of breeding, all of which could be affected by contaminants. Documented cases of decreased embryo viability, immunosuppression, altered stress response, alterations in thyroid function, and metabolic abnormalities on Lake Ontario herring gull colonies located at Hamilton Harbor, Toronto and at Kingston suggest that demographic parameters such as survival and recruitment could be affected in this population (C. Hebert, L. Shutt, G. Fox, Canadian Wildlife Service unpublished data).

A recent development in the health of Lake Ontario's nesting colonial waterbirds and migratory waterbirds concerns die-offs of large numbers of cormorants, terns, gulls and long-tailed ducks, in the late summer and autumn. During 2004 and 2005, over 4,000 dead birds were found washed up on shorelines or found dead on roosting islands, mainly in eastern Lake Ontario (from Pres'quile east through to Kingston area on Canadian side) (Pekarik et al. 2005, CWS unpublished data). Post-mortem examination indicated that the most likely cause of death was type E Botulism. The die-offs may have effects on populations of colonial waterbirds, in particular populations whose numbers are small or geographically restricted. For example, with the great black-backed gull, a species whose main breeding area on the Great Lakes is located in eastern Lake Ontario on islands and shoals surrounding Prince Edward County, the number of individuals found dead exceeds the known breeding population (Weseloh et al. 2003). Over the last 5 years there has been a nearly 70% decline in the number of breeding pairs of black-back gulls on the Canadian side of Lake Ontario (L. Shutt, CWS unpublished. data). Continued monitoring for bird deaths along Lake Ontario's shorelines and islands should provide the Lake Ontario LaMP and its partner agencies with updates on their status and an assessment of biodiversity.

Mink & River Otter

Settlement, trapping, and habitat losses during the eighteenth century are believed to have contributed to major population declines for both species. Prior to these changes, the river otter had one of the largest geographic ranges of any North American mammal and was found in all major U.S. and Canadian waterways. As with the bald eagle, there was indirect evidence at the time of the BUI determination which suggested that reproduction of Lake Ontario mink in nearshore areas was affected by persistent toxic contaminants. In the 1960s, reproductive failures of ranch mink that had been fed Great Lakes fish led to the discovery that mink are extremely sensitive to PCBs (Hartsough, 1965; Aulerich and Ringer, 1977). Laboratory experiments had shown that a diet of fish with PCB or other dioxin-like contaminant levels comparable to those found in some Lake Ontario fish can completely inhibit mink reproduction. However, the fact that mink are highly opportunistic and may rely on muskrat, rabbits, and mice for the bulk of their diet in some locales made it difficult to estimate the impact that environmental contaminants were having on the populations of this species. Otters, on the other hand, rely almost exclusively on fish for their diet, but there was little information on the sensitivity and exposure of otters to PCBs and other contaminants. Laboratory studies corroborated that levels of PCBs and dioxin-like contaminants in the food chain may have been limiting the natural recovery of both mink and otter populations.

A recent review, funded by the Lake Ontario LaMP, was done on trapping and sighting data (Bouvier 2002). This review did not have a contaminants component. However, harvest statistics from trappers although biased by pelt prices and the number of trappers, clearly showed that mink and otter populations in the Lake Ontario basin are healthy. Sighting data in both New York and Ontario supported the trapping data. Although data was lacking for urbanized areas, the author concluded that the Lake Ontario basin supports healthy populations of both mink and otter. The author also concluded that healthy mink and otter populations suggest that habitat for mammals is in a healthy state too. These conclusions suggest that the mink and otter indicator objective has been met.

A different survey about contaminants in trapper-caught mink was conducted by Canadian Wildlife Service in 2000-2005 in Lake Ontario. Results indicated that animals collected from coastal wetlands or tributaries within 4 km of Lake Ontario in Kingston, Bay of Quinte, Port Hope and Hamilton contained concentrations of PCBs and other chlorinated hydrocarbons and mercury well below those associated with negative reproductive effects (P. Martin, CWS unpublished data). .

Snapping Turtles

Although there has been no evidence of snapping turtle declines in Ontario due to persistent organic contaminants, hatching mortality and deformities were higher at some Lake Ontario populations in the late 1980s. There was indirect evidence that depressed hatching mortality and deformities were associated with PCBs and dioxin-like compounds (Bishop et al. 1991), although direct linkages were not made. Liver enzymes consistent with exposure to PCBs and similar compounds were elevated in hatchlings from more contaminated sites along the north shore of Lake Ontario (Bishop et al. 1998). A more recent assessment by the Canadian Wildlife Service (2003-2004) suggests that deformities rates and hatching success of turtles from some of the same sites assessed in the late 1980's did not differ from inland reference sites (K. Fernie, CWS in published data). However, subtle health effects have not been fully evaluated.

4.4.3 Loss of Fish and Wildlife Habitat

Fish and wildlife habitat is a lakewide impairment caused by artificial lake level management, the introduction of non-native species, and physical loss, modification, or destruction, such as deforestation and damming of tributaries. Binational evaluations were initiated to evaluate potential options to mitigate these impacts. An evaluation of habitat conditions from 1980 to 1990 did not identify persistent toxic substances as a significant cause of lakewide habitat loss or degradation.

Physical Habitat

The early colonists began to alter the seasonal flows of Lake Ontario tributaries by clearing land. As the land was cleared, water temperatures began to rise, siltation increased, and aquatic vegetation (which provides cover for young fish) was lost. Further, the damming of Lake Ontario tributaries and streams impeded migration of salmon and other native species to their spawning and nursery grounds. The combined impacts of all these factors were devastating to nearshore, tributary, and wetland habitats. Wetlands provide vital habitat to many species of Lake Ontario's wildlife. It has been estimated that about 50 percent of Lake Ontario's original wetlands throughout the watershed has been lost. Along the intensively urbanized coastlines, 60 to 90 percent of wetlands have been lost. These losses are a result of the multiple effects associated with urban development and human alterations, such as draining wetlands to establish agricultural land, marina construction, dyking, dredging, and disturbances by public utilities. Natural processes, such as erosion, water level fluctuations, succession, storms, and accretion, contribute to the loss of wetlands as well.

At the time of the BUI assessment, approximately 80,000 acres of Lake Ontario's wetlands remained. The largest expanses are still located in the eastern portion, along the coastline of Presque'ile Bay's Provincial Park in Ontario and in Mexico Bay in New York. The pressures of urban and agricultural development continue to threaten wetlands as the public wishes to locate along the lakeshore, have larger marinas in river mouths, achieve more efficient stormwater removal from streets and properties, or till marginal wetlands in the watershed during dry years. Major government initiatives, including education and regulatory controls, have done much to reduce or prevent the loss of wetlands. More than 20 percent of Lake Ontario's wetlands are fully protected (parks) while additional areas are subject to a variety of municipal, state/provincial, or federal rules, regulations, acts, or programs. Stemming continued losses of wetlands requires action at the most efficient level of organization, and opportunities to protect, restore, or replace these valuable habitats need to be explored.

Artificial Lake-Level Management

There is considerable evidence that the management of lake levels has inadvertently reduced the area, quality, and functioning of some Lake Ontario nearshore wetlands. Nearshore wetlands are important to the ecology of the lake because they provide habitat necessary for many species of fish and wildlife to successfully live and reproduce. These wetlands may be unique or of limited quantity in the number and types (diversity) of plants and soil benthic type (i.e., rocks, sand, or silt). Without wetlands of suitable quality and quantity, many species of fish and wildlife would be at risk. There is also significant concern among the citizens living along the shoreline of Lake Ontario that lake level management is causing increased erosion and property loss. High lake levels are associated with accelerated rates of erosion and property loss in areas susceptible to lake-induced erosion.

Lake level management was first recommended to limit flooding and erosion in the Lake Ontario basin and to prevent flooding of major metropolitan areas along the St. Lawrence River, such as Montreal. Lake Ontario level and St. Lawrence River flow regulations are also used to benefit commercial navigation and hydropower production. The International Joint Commission (IJC) was established in 1909 by the Boundary Waters Treaty to serve as an impartial group with jurisdiction over boundary water uses. The IJC consists of three U.S. members appointed by the President of the United States and three Canadian members appointed by the Prime Minister of Canada. Plans to artificially manage Lake Ontario water levels began in 1952 when the IJC issued an Order of Approval to construct hydropower facilities in the international reach of the St. Lawrence River at Cornwall, Ontario and Massena, New York. The hydropower facilities were completed in 1960. The IJC amended its order in 1956 to include regulation criteria designed to reduce the range of lake levels and to protect riparian and other interests downstream in the Province of Quebec. This amended order also established the International St. Lawrence River Board of Control to ensure compliance with provisions of the Orders. The St. Lawrence Board consists of ten members chosen by the IJC for their technical expertise.

Lake levels are currently regulated by Plan 1958-D. This plan sets maximum and minimum flow limitations which change week to week to provide adequate hydropower production and, at the same time, maximize depths for navigation and provide protection against flooding in the St. Lawrence River. Authorization may be requested by the Board to deviate from Plan 1958-D when supplies are greater or less than those upon which the plan was developed. During the development of this plan, environmental and recreational factors were not considered. As recommended by the IJC's Levels Reference Study Board, the St. Lawrence Board has been investigating the possibility of changing the current plan and/or procedures to better address environmental and recreational concerns (see Section 10.2.3).

Several environmental issues have been identified in studies completed by the Levels Reference Study Board in 1993. As a result of lake level management, Lake Ontario wetlands are no longer experiencing the same range of periodic high and low water levels. This reduction in range has resulted in some wetlands becoming a monoculture of cattails -- a greatly reduced biodiversity of nearshore areas. In addition, the current four foot range in fluctuation for Lake Ontario is too narrow to preclude cattail overpopulation by modifying the timing of water level highs and lows from their natural cycle. This can have a devastating effect on wetlands, often resulting in too little water for fish and wildlife reproduction purposes, but has provided benefits to recreational and commercial boating.

Regulation of lake levels is difficult because changes in precipitation rates and winter ice cover are unpredictable and limit our ability to manage water levels. Shoreline erosion is a natural occurrence caused by the energy present in water at the shoreline. The nature of erosion that may occur is related to the soil type and elevation, wind, current, and water level at the time. Where the energy in the water can be absorbed, erosion will be slow, but where the makeup of the shoreline is unstable, the effects of erosion take place more quickly. Erosion of certain areas of Lake Ontario's shoreline is a natural process that will inevitably occur.

Non-native Species

It is difficult to predict some of the more subtle interactions that might develop between newly introduced non-native species, naturalized non-native species, and native species. This evaluation is further complicated by other chemical and physical changes that are taking place in the basin concurrently. It was clear, however, at the time of the 1997 BUI assessment, that non-native species were having a significant impact on the Lake Ontario ecosystem and continue to do so. The Lake Ontario ecosystem has experienced several significant impacts by non-native species some of which are discussed in degradation of fish populations (section 4.4.6). The designation of the sea lamprey as a non-native species in Lake Ontario is questionable. Nevertheless, the sea lamprey has clearly had a negative impact on some native species. Currently it is being controlled at or near levels targeted by the Lake Ontario Committee of the Great Lakes Fishery Commission (NYSDEC 2005; OMNR 2005). Although not considered a major limiting factor, lamprey predation on lake trout may add to the cumulative mortality currently hampering lake trout restoration efforts.

Other non-native species have become important components of the Lake Ontario food chain forever altering the biological component of fish and wildlife habitat. These species include smelt and alewife, which are now the dominant forage fish in the offshore (see Chapter 2, and section 4.4.6 in this Chapter). The round goby is very quickly becoming an important component of the nearshore food web and there is lake trout diet information from the east and west ends of Lake Ontario that show goby to be important to their diets (OMNR, unpublished data; Clark et al, Great Lakes Fishery Commission, Lake Ontario Committee Meeting 2005). The Dreissenids have become very important diet items for lake whitefish, freshwater drum and probably most zooplanktivores ingest their veligers. They are also clearly important to some waterfowl.

Some species like the rudd (uncommon in Bay of Quinte) and the blueback herring (observed near Oswego) have not become well established in Lake Ontario. The ruffe has not been observed in Lake Ontario yet but is found in Lake Superior and Lake Huron. Asian species like grass carp have been seen in the lake near Toronto. Five bighead carp have been observed in Lake Erie (Morrison et al, 2004). The impact of these rarer non-native species on the nearshore food webs is not known but Asian carp like bighead and silver carp can displace other native fishes in the nearshore and in rivers should they be introduced into Lake Ontario.

Zebra and quagga mussels have altered the bottom of Lake Ontario. Their presence on the bottom surface of the lake has dramatically altered the habitat, making it less suitable for some native invertebrates. Their ability to increase water clarity in nearshore areas has increased the area for and amount of macrophyte and attached algae growth. Their washed up shells are also negatively impacting beach use. In addition, there are increased maintenance costs associated with keeping drinking water and cooling water intakes free of these mussels. It is exceedingly difficult and costly to control non-native species after they have been introduced to an ecosystem, so control programs have concentrated on preventing new introductions and inhibiting the spread of existing species.

An important component of these control programs is the US federal regulation that requires ocean-going ships to exchange their ballast water at sea before entering the St. Lawrence Seaway. This requirement seeks to ensure that any exotic species present in the ballast water will not be released into the Great Lakes. It is believed that zebra mussels, the round goby, and the ruffe were all introduced to the Lakes in this way. Stopping the initial introduction by ocean going vessels is critical as, once in the Great Lakes, Great Lakes vessels (that are not recognized in this legislation) can move non-native species throughout the system. The goby and *Dreissena* mussels probably arrived in eastern Lake Ontario via a Great Lakes vessel.

The United States and Canadian Coast Guards are working to limit the introduction of non-native species through transoceanic shipping. In addition to the ballast water exchange requirement, chemical treatment measures may be necessary to deal with any organisms that may be left in the tanks after ballast water exchange.

4.4.4 Degradation of Benthos

Degradation of benthos is a lakewide impairment caused by the introduction of zebra and quagga mussels. Benthic macroinvertebrates, often called benthos are small insect-like organisms that live in the bottom sediments of the lake and are an important food source for many types of fish. Dramatic changes have occurred within Lake Ontario's benthic community since the 1950s due primarily to significant reductions in nutrient loadings and changes in the numbers and types of fish that feed on benthic organisms. These impacts may have overshadowed any past or present lakewide impacts from toxic contaminants.

Studies completed shortly before the second BUI assessment in 2002 have given us a better picture of the potential impacts of contaminants in Lake Ontario sediment on benthic communities. Sediment samples were collected throughout Lake Ontario in 1997. Pollution sensitive benthic organisms were then exposed to these sediments under laboratory conditions to evaluate sediment toxicity. Results showed that contaminant concentrations in lake bottom sediments posed little to no acute toxic threat to these sensitive test organisms. Additional information will be needed to assess the potential for contaminants to have long-term chronic impacts on these organisms.

Although contaminant-related impacts on benthos are not a concern for the open lake, localized toxic contaminant impacts on benthic organisms have been documented in some Lake Ontario Areas of Concern with elevated levels of sediment contamination. These problems are being addressed through local Remedial Action Plans.

It is clear that the introduction of the zebra mussel in the late 1980s has had a detrimental impact on Lake Ontario benthos. The Quagga mussel, which arrived in Lake Ontario with the zebra mussels, is capable of living in colder, deeper waters than the zebra mussel. These mussels filter water to feed on microscopic phytoplankton and other organic material, thereby reducing the amount of food available to other benthic organisms. The filtering action of the mussels also contributed to the dramatic increase in water clarity. At the same time, populations of some important native benthic organisms have generally declined. Section 10.2.2 provides further information regarding the zebra and Quagga mussels.

Prior to the arrival of the zebra mussel, populations of the small shrimp-like *Diporeia* were the dominant benthic organisms in the lake. Typically, a few thousand of these organisms were present in a square meter of lake bottom and provided an important source of food for fish. A decade after the zebra mussel invasion, as few as ten of these organisms can be found per square meter in waters up to 200 meters deep, while the *Diporeia* had disappeared from most locations in less than 80 m depth. Although the mussels are suspected to be the cause of these declines, a clear cause-effect relationship has yet to be established.

Some less important nearshore native benthic species have benefited from the zebra mussel invasion. Populations of some shallow water (less than 10 meters-deep) native benthic organisms that prefer the habitat created by zebra mussel shells and can feed on the mussel's waste products have increased. Nearshore fish, such as perch, smallmouth bass and introduced goby that feed on these organisms, are benefiting from the increase in these benthic populations.

Following the 2002 BUI assessment, additional studies of Lake Ontario benthic organisms, phytoplankton, and zooplankton were initiated to develop a better understanding of the rapid changes occurring in Lake Ontario's food web.

4.4.5 Degradation of Nearshore Phytoplankton Populations

Degradation of nearshore phytoplankton populations is a lakewide impairment caused by the introduction of zebra and quagga mussels. Healthy and balanced communities of phytoplankton and zooplankton are essential components of all normal aquatic ecosystems. Without these microscopic plants and animals, there would be no fish in lakes. Lake Ontario phytoplankton and zooplankton data have been collected during the past few decades as part of Canadian and U.S. monitoring programs. Changes in the structure of plankton communities and their relationship to nutrient levels have been examined in nearshore, offshore, and embayment habitats in order to better understand whole-lake processes.

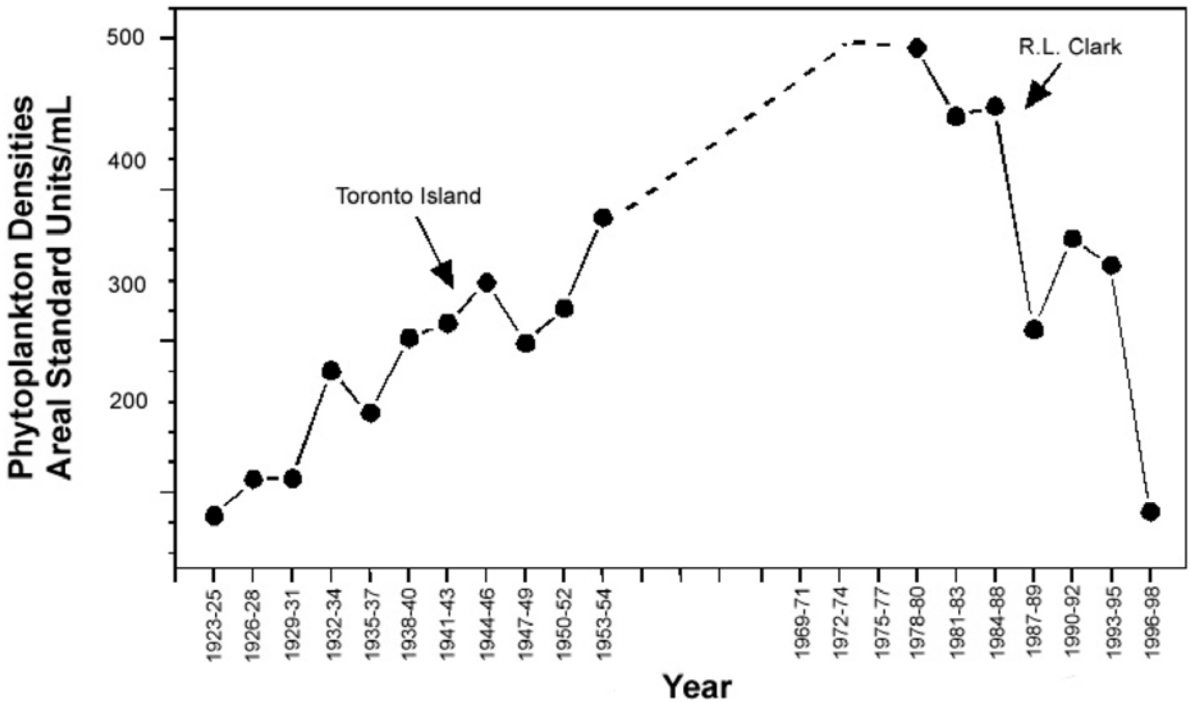
In recent decades in Lake Ontario, these communities have been influenced by reductions in inputs of phosphorus from municipal waste treatment facilities, invasions by exotic species and changes in fish communities. As with the benthic community, these changes may have overshadowed any impacts that contaminants may have had on phytoplankton and zooplankton populations in the past. There is no indication that current levels of contaminants pose a concern for phytoplankton and zooplankton populations. However, through bioaccumulation, even low concentrations of contaminants in phytoplankton and zooplankton can pose concerns for higher level predators such as fish and waterbirds. At the time of the 2002 BUI assessment, the potential impacts of exotic mussels and predatory zooplankton were recognized as the greatest threat to these native populations.

Phosphorus and Phytoplankton

The Lake Ontario phytoplankton community is controlled by both nutrient supply, typically measured in terms of total phosphorus, and by the size of zooplankton populations that feed on phytoplankton. During the 1940s to the 1970s excessive discharges of nutrients from agriculture and wastewater discharges resulted in abnormally high Lake Ontario phosphorus levels. The result was an explosion in the growth of phytoplankton and algae creating severe water quality problems. The U.S. and Canada implemented phosphorus controls at wastewater treatment plants beginning in the 1970s and reduced total phosphorus levels in the open lake by 30 percent over a 15-year period. Nearshore waters that had the highest nutrient levels saw declines in phosphorus levels well over 50 percent.

Several long-term studies have documented changes in phytoplankton. Collections of phytoplankton samples from Toronto drinking water intakes provide a historical perspective on long-term trends and their response to changing nutrient levels (Figure 4.1). These collections show that phytoplankton densities doubled between the 1920s and the 1950s in response to increasing and excessive nutrient levels. Beginning about 1980, this trend was reversed, reflecting the success of phosphorus controls which have maintained open lake total phosphorus concentrations at or below a level designed to prevent nuisance growths of algae.

Figure 4.1 Phytoplankton Densities from Toronto-based Lake Ontario Water Treatment Plant Intakes, 1923 – 1998



Source: Nicholls 2000.

Since the arrival of the zebra and quagga mussels, there has been concern that this species could alter the Lake Ontario food web in a number of ways. The impacts of the filtering action of Dreissenid mussels on nearshore phytoplankton densities were seen as early as 1992. By 1998, zebra mussel feeding apparently had reduced phytoplankton densities by more than 90 percent in some inshore areas. The composition of phytoplankton communities also changed, with edible types of algae decreasing and less edible forms increasing.

Normally, chlorophyll a concentrations are directly proportional to nutrient levels. However, at the time of the 2002 BUI assessment, an apparent "decoupling" of chlorophyll a and nutrients was observed in some nearshore waters where increases in nutrients were not accompanied by expected increases in chlorophyll a. It was suspected that this decoupling reflected grazing activity by zebra and quagga mussels.

Research continues to provide a better understanding of seasonal changes in phytoplankton populations in nearshore and offshore waters and embayments. Studies undertaken in the mid-1990s in Canadian waters found that nearshore spring phytoplankton densities were six to eight-times higher than summer densities at the eastern end of the lake. Offshore stations showed much less difference between spring and summer phytoplankton biomass. Spring phytoplankton density peaks were confined to April and May at eastern Lake Ontario nearshore sampling locations, but often extended into June at western sampling sites, indicating higher nutrient levels related to Niagara River inputs. With continued declines in nutrients entering Lake Ontario via the Niagara River, recent studies now find little difference between eastern and western Lake Ontario nutrient levels.

4.4.6 Degradation of Fish Populations

Prior to 2005, this BUI was considered not impaired. The reasons are described in the Lake Ontario LaMP 1998 Stage 1 report and in the background for Lake Ontario in this status report (see Chapter 2). At the time of the last assessment, Lake Ontario's native species were showing signs of recovery with high abundances of walleye, lake whitefish, wild reproduced lake trout, and deep water sculpin. The Pacific salmonids were all being managed based on prey supply and the ecosystem appeared balanced. But, since that time the colonization of Lake Ontario by non-native species, continued pressures from fishing, rapid changes in abundance of prey fishes and subsequent declines in the survival of lake trout, lake whitefish and walleye, and reduced growth of virtually all Pacific salmonids clearly showed that the fish populations in Lake Ontario are stressed. Because of the obvious changes occurring in Lake Ontario, the Lake Ontario LaMP Management Committee followed the Working Group recommendation to re-assess the fish populations BUI.

The re-assessment of this BUI took into account the LaMP's primary ecosystem objective,

"Aquatic communities: The waters of Lake Ontario shall support diverse and healthy reproducing and self-sustaining communities in dynamic equilibrium, with an emphasis on native species" (see Section 3.2.2).

Thus, the rating of degraded relates to achieving the objective as stated. Currently, there are two ecological indicators for this BUI and they are prey fish and lake trout (see Sections 3.3.2 and 3.3.3). Lake trout are used as an indicator of the health of the offshore fish community and prey fish are used as an indicator of both offshore and nearshore fish community health.

Lake trout restoration efforts have not been successful in achieving the objective of self sustaining populations of lake trout. USGS trawls for lake trout clearly show that natural reproduction occurs at very low levels (USGS/NYSDEC, 2005). In addition, there are signs of poor survival of recently stocked lake trout, low but stable harvest and catches in agency assessment programs, and changes in adult lake trout distribution favoring the southwest portion of the lake (NYSDEC, 2005; OMNR, 2005). Currently, none of the wild produced lake trout indicator targets have been met in spite of meeting adult biomass and fish and sea lamprey mortality targets (See Chapter 3 lake trout indicator).

A health issue resulting from the reliance on a diet of alewife and smelt is early mortality syndrome. Alewife and rainbow smelt are known sources of thiaminase, an enzyme that causes thiamin deficiency in adult fish, particularly salmon and trout (Honeyfield et al, 2005 and references therein). Thiamin deficiency results in increased mortality of embryonic and larval fish as well as secondary disease states that lead to increased mortality at older life stages (Brown et al., 2005). The Lake Ontario Committee of the Great Lakes Fishery Commission recognizes thiamin deficiency as an important issue and research on sources of thiaminase, effects of low thiamin and remedies for low thiamin are underway now. Native prey fishes such as the deepwater ciscoes and deepwater sculpin, though extirpated or very rare, contain low levels of thiaminase (Honeyfield et al. 2005), therefore, fishery managers are examining the possibility of restoring some of these native prey fish.

The focus of restoration should be on understanding the factors causing increased mortality during the lake trout's early life history. Potential bottlenecks hampering lake trout restoration are: increased mortality on shallow reefs from shock and turbulence; predation on eggs by benthic predators; increased predation on young lake trout by alewife when their abundance is high and increased predation on young lake trout by other salmonids when alewife abundance is low; diet caused thiamin deficiencies, and predation of young fish particularly by gobies (Fitzsimons et al, 2003). As well, exploitation of adult fish, even at a very low level, can hamper any restoration effort (Christie et al, 1987). Addressing these bottlenecks and reducing or stopping lake trout exploitation may allow the Lake Ontario LaMP to meet its objective for the lake trout indicator and take one step towards reclassifying the fish populations BUI.

The prey fish community is dominated by a non-native species. The prey diversity in order of highest biomass includes alewife, 3-spine stickleback, with rainbow smelt and slimy sculpin a distant 3rd and 4th (OMNR, 2005). Deepwater sculpin are very rare but have been captured in larger numbers in 2005 than seen in many years (O'Gorman, personal communication). There are no deep water ciscoes in the offshore of the main basin and lake herring are restricted to the eastern or Kingston basin. All prey species are self sustaining at present. The diversity of prey species although seemingly adequate with respect to the measures for the indicator, is heavily biased towards alewife (Chapter 3, Section 3.3.2) and does not support healthy predator populations as shown by lake trout indicator and the condition of other top predators. The purpose of the objective is to have a prey base with enough diversity and biomass to achieve stable predator prey relationships. At the time of the last assessment, fisheries agencies had not set a target measure for prey biomass that would support the predator fishes and this target is a research priority with the Lake Ontario Committee. A review of the changes in prey and predator fish species, zooplankton and the entire food chain is needed to assess the stability of predator prey relationships and health of the predator populations supported.

Assessing the status of the prey fish with respect to the indicator objective suggested in Chapter 3 requires using measures of abundance, age and size distribution of the prey fish. The offshore prey fish are dominated by alewife (Mills et al, 2004). Alewife biomass is lower in recent years than in the 1980s and early 1990s (NYSDEC, 2005; OMNR, 2005). Body condition, a function of weight at a given length, of older alewife is improving, suggesting that the abundance of this prey fish has declined. It is important to note that the abundance of rainbow smelt, slimy sculpin and deepwater sculpin are low to near zero, respectively.

In the offshore, the top predators are Chinook salmon, rainbow trout, lake trout, Coho salmon and Atlantic salmon. Assessment of Atlantic salmon is very poor in Lake Ontario and focuses more on tributaries. However, Atlantic salmon is a native species, once extirpated, that is surviving in Lake Ontario due primarily to restoration efforts. The Lake Ontario Committee's fish community objective for the offshore pelagic fish community is to have a diversity salmon and trout with Chinook as the primary species and due to stocking rates and wild reproduction Chinook salmon dominate all other salmonines (GLFC, 1999; Mills et al, 2004; NYSDEC, 2005; OMNR; 2005). They are well represented in assessment of the offshore food web and as such, are an excellent indicator of changes in their prey base. Their diet is almost solely alewife. Chinook condition (weight at length) is closely related to body condition of alewife. The weight of 900 mm Chinook salmon has steadily declined and reached an all time low in 2004 suggesting these fish are not finding enough food (NYSDEC 2005; OMNR 2005). Since 2000, an average of 2.2 million Chinook salmon has been stocked into Lake Ontario. Angler catch rates show that the abundance of Chinook may have increased in the last 3 years. It is a fair assumption that when coupled with wild reproduction estimates (at least 25%, Ian Craine, University of Toronto, unpublished data), the abundance of Chinook has increased. The increase in the number of Chinook in Lake Ontario combined with the decrease in prey fish biomass is likely the reason why Chinook weight at age has declined.

Other salmonids have shown signs of decreased growth too. Coho salmon continue to show signs of reduced condition factor, and variable wild reproductive success (OMNR 2005). The number of rainbow trout returning to the Ganaraska River in Ontario, has been steadily declining since about 1989 (OMNR 2005). It has been suggested that the declining return rate is due to reduced survival of wild and stocked rainbow trout soon after they enter Lake Ontario and as mortality estimates of age 3+ fish have not changed over the same period of time; it is unlikely that fishing mortality has increased (Bowlby, J. personal communication). One plausible alternative is increased predation of young rainbow trout soon after entering the lake. This phenomenon is also suggested for lake trout soon after stocking directly into the lake.

Both NYSDEC and OMNR stock significant numbers of Coho salmon and rainbow trout into Lake Ontario and its tributaries every year and no reductions in numbers stocked have occurred for several years (NYSDEC, 2005; OMNR, 2005). Both species also show varying levels of wild reproduction which adds to the number of top predators in the lake and have established wild runs in several tributaries (Christie, 1973). The cumulative effects of increased predators and decreased prey fishes could be an imbalance in the ratio of predators to prey.

In nearshore areas walleye and cormorants also eat alewife. Walleye and cormorants both seek other prey items when alewife are not abundant. Nevertheless, they both increase the demand on alewife. Lake trout, Chinook salmon and rainbow trout are resident in the Kingston basin too. Recent surveys of the Kingston basin suggest alewife abundance is lower there than in the rest of the lake (Casselman and Scott, 2003; Mills et al, 2004; OMNR, 2005).

There is one other good indicator of predator prey imbalance and this occurs in the lower food web. Although under review, zooplankton are also in a state of flux due to two recently introduced non-native species, the fish hook and spiny water fleas (*Cercopagis pengoi* and *Bythotrephes longiminus,* respectively). The fish hook did very well and for several years was the more abundant of the two species. The fish hook water flea is less susceptible to alewife predation and shows less response to alewife abundance. Johannsson (2003) suggested that the reason the spiny water flea never became abundant while the fish hook water flea did was due to alewife predation. Spiny water flea is a prey item for alewife so when alewife abundance declines one would predict spiny water flea abundance to increase. In 2003 and 2004, the abundance of spiny water flea has increased (Johannsson pers. comm.).

Considering trends in alewife indices and that of the other prey species, the changes in growth of Chinook salmon, the continuous stocking rate of predator species, the abundance of other predators, the contribution of 'wild' produced fish and the trends observed in the lower food web, it is not difficult to surmise that the balance between predators and prey has changed since the last assessment of this BUI. From an ecological perspective, the downward trends in size at age, reduced returns of wild fish, poor survival of recently stocked fish, reduced biomass and abundance of alewife and rainbow smelt both in main basin and in Kingston basin all suggest an impairment of 'fish' populations.

Perhaps the epitome of impaired Lake Ontario fish populations is shown by lake whitefish, an important native prey fish. This species had appeared to recover through the 1980s. Lake whitefish declined precipitously soon after the colonization of the Bay of Quinte and eastern Lake Ontario by dreissenid mussels (Hoyle et al, 1999; Hoyle et al, 2003; Chapter 2 this report). During the mid-1990s, lake whitefish were appearing emaciated and Hoyle et al (2003) suggests that dead whitefish caught in bottom trawls during 1998 died from starvation, perhaps indicating a drastic and rapid change in the food web for the entire eastern basin as this species is resident in the Kingston basin and throughout the Bay of Quinte, in Lake Ontario and Chaumont Bay, NY. The populations of whitefish are still fished, and still reproducing but the survival of their young appears to be very low as of 2004 (OMNR 2005). Research is currently underway to address potential causes but there are no remedies in sight.

Finally, the BUI "degradation of fish populations" is impaired simply as a result of the status of other BUIs such as contaminants in fish, fish habitats, and phytoplankton within their habitats which are all impaired. As these BUIs are all interconnected, a discussion of remediation needs to be inclusive.

The primary objective for the LaMP is to have self sustaining fish populations with a preference towards native species. Today, there is no evidence that native species such as lake whitefish, lake trout, sculpins, and their food, *Diporeia* will recover in the foreseeable future. Species like Atlantic salmon remain due to a small stocking effort. There are pathological issues directly related to non-native prey fishes and thiamin in their predators, especially lake trout and Atlantic salmon. Also, it is impossible to ignore that the GLQWA has reduced phosphorus and this, combined with the filter feeding effects of dreissenid mussels, has resulted in reduced primary production, less secondary production, and less production of prey species such as alewife, smelt, sculpins and lake whitefish.

As mentioned earlier, the status of fish populations is a key concern of the Lake Ontario LaMP and also of the GLFCs Lake Ontario Committee (LOC). The LOC is in the process of updating its Fish Community Objectives (FCOs) which state clear fish community objectives based on a holistic ecological approach. The Lake Ontario LaMP will work with the LOC to develop its revised FCOs over 2006-2007.

4.5 Unimpaired Lakewide Beneficial Uses in Lake Ontario

The LaMP's Stage 1 beneficial use assessment determined that the following beneficial uses were unimpaired on a lakewide basis:

- Tainting of fish and wildlife
- Fish tumors
- Restrictions on dredging activities
- Eutrophication or undesirable algae
- Drinking water restrictions or taste and odor problems
- Beach closings
- Degradation of aesthetics
- Degradation of zooplankton populations*
- Added costs to agriculture and industry

* Under review.

The following sections provide the basis for these determinations.

4.5.1 Tainting of Fish and Wildlife Flavor

The contamination of surface waters by certain types of organic contaminants, such as the class of chemicals known as phenols, can taint fish and wildlife flavor. During the 1950s, 1960s, and 1970s, levels of phenols near the mouth of the Niagara River often exceeded standards designed to prevent tainting of fish and wildlife flavor. Since that time, improvements in wastewater treatment systems and remediation of uncontrolled hazardous waste sites have dramatically reduced the amounts of these substances being discharged to surface waters. Today, levels of phenols are well below levels of concern.

At the time of the Stage 1 beneficial use assessment, there were no existing reports that indicated tainting of fish and wildlife flavor was a concern for the open waters of Lake Ontario. Neither was this potential impairment identified as a problem in any nearshore areas of the lake. Evaluating this type of impairment is difficult given the very subjective nature of taste. Studies have shown that fish consumers cannot consistently detect the difference between tainted and non-tainted fish. The length of time and preservation methods used before cooking fish can also contribute to taste problems.

4.5.2 Fish Tumors

Fish tumors are more common in some species of nearshore fish, such as brown bullheads and white suckers, than others; however, it is very difficult to determine what the natural tumor incidence rate is for a particular location (Hayes et al., 1990). Relatively high levels of tumors can be found in fish from both clean and polluted water bodies. For example, skin and liver tumors have been documented in fish taken from relatively pristine drinking water reservoirs in New York and Pennsylvania, where no elevated levels of carcinogens [such as polycyclic aromatic hydrocarbons (PAHs)] have been detected in sediments or water (Bowser et al., 1991). This fact complicates the process of selecting a control or background site to which the incidence of fish tumors in a contaminated area can be compared. Viruses, genetic differences, and naturally occurring carcinogens, in addition to chemical contaminants, are thought to have a role in fish tumor development.

The presence of tumors in Lake Ontario fish was first noted in the early 1900s before persistent toxic contaminants became a problem in the lake. Liver tumors were first identified in wild fish in the 1960s. However, a temporal correlation between any change in the incidence of fish tumors and the onset of the severe environmental contamination problems of the 1960s cannot be firmly established because the first detailed studies of fish tumors in Lake Ontario were not conducted until the 1970s.

A 1996 collection of spawning walleye in the Salmon River, a tributary of the Bay of Quinte, found that the frequency of liver tumors increased with the age of the fish and was more prevalent (87.5%) in female walleye greater than 14 years of age. The frequency-age relationship is comparable to previous walleye collections in the St. Lawrence River. The tumors are non-invasive and it is possible that the tumors are a naturally occurring phenomenon in old walleye. However, before any interpretation of probable cause can be made, it will be necessary to determine the rates of liver tumors in similarly aged walleye from other more pristine habitats.

Contaminant-related fish tumors would be expected to be most prominent in Lake Ontario AOCs where there are generally higher contaminant levels than in open water areas. To date, Hamilton Harbour is the only Lake Ontario AOC which lists this impairment. The Oswego Harbor AOC completed a fish tumor study shortly before the BUI assessment that found no impairment. The Toronto and Region, Bay of Quinte, and Eighteenmile Creek AOCs have each indicated that additional information is necessary to fully evaluate the status of this impairment. An assessment of the status of this beneficial use impairment is currently underway in all the Canadian AOCs (except for Port Hope), as part of Environment Canada's Fish and Wildlife Health Effects and Exposure Study.

As there were few reports of tumors in open water fish, fish tumors were not considered to be a lakewide impairment in the Stage 1 beneficial use assessment. The lakewide status of this impairment will need to be periodically evaluated as new information is developed on the incidence of tumors in open water fish as well as the role of contaminants and other factors involved in fish tumor development.

4.5.3 Restrictions on Dredging Activities

Localized areas of sediments with elevated levels of persistent toxic contaminants are found in some Lake Ontario harbors and river mouths. Periodic dredging of these sediments is necessary to maintain shipping and small craft channels. This beneficial use impairment is not considered to be a lakewide impairment because dredging restrictions do not pertain directly to open water areas; however, this impairment is a concern in a number of localized nearshore areas and AOCs.

Criteria that are used to assess dredging activities are not based on whether or not dredging should take place, but rather the mode of dredged material disposal. There are five main ways to dispose of dredged sediments. Clean, uncontaminated sediments can either be placed on beaches or reused along shorelines as fill. The other three methods of disposal, offshore, upland, and confined, are based on the degree of contamination of the sediments. The most highly contaminated sediments require confined disposal in special contaminated sediment facilities. Less contaminated sediments can be stored in landfills or disposed in deep offshore waters.

The Canadian Department of Public Works and Government Services used to maintain a register for Canadian navigational dredging project data. The register recorded location of dredging, volume of sediments dredged, disposal methods, and chemical analysis data. Information on dredging activities was registered from 1975 until a few years prior to the Stage 1 assessment , when navigational dredging activities declined in the Canadian sections of the Great Lakes. The Hamilton Harbour, Toronto and Region, Port Hope, and Bay of Quinte AOCs all continue to identify dredging restrictions as an impairment. In addition to Lake Ontario LaMP critical pollutants (e.g., dioxins and furans, mercury, PCBs, DDT and its metabolites) sediment concentrations of other organic pollutants (e.g., PAHs, oils and grease), metals (e.g. copper, lead, and zinc) and nutrients (e.g. nitrogen and phosphate) have been identified as elevated above Canada's federal or provincial sediment quality criteria in some near-shore areas (see Screening Level Surveys of Lake Ontario Tributaries, section 6.5.3.1).

In the United States, the Army Corps of Engineers (USACE) oversees and approves dredging projects in coordination with USEPA, NYSDEC and NYSDOS. At the time of the Stage 1 beneficial use assessment, there were no restrictions on dredging or dredged material disposal activities in the U.S. waters of Lake Ontario due to contaminated sediments. Sediment dredged from major Lake Ontario harbors met USEPA and USACE guidelines for open water disposal. No dredging restrictions were identified by the RAPs for Rochester Embayment or Oswego Harbor. The only U.S. dredging restriction applied to the type of dredging methods that could be used on the Genesee River. In response to local concerns regarding excessive turbidity levels, dredging techniques that caused excessive turbidity in the river were not allowed. Contaminated sediments were not a cause of these limitations.

In February 1998, USEPA and USACE finalized the Inland Testing Manual, which laid out stringent testing protocols for dredged material disposal in inland waters. Then, over the next 12 to 18 months, USEPA and USACE worked with their partners to develop a regional manual to implement the national testing protocol in the New York State portions of Lakes Ontario and Erie. The status of this beneficial use could change if future dredging projects encounter sediments that exceed these new, more stringent testing requirements.

4.5.4 Eutrophication or Undesirable Algae

Eutrophication is a process in lakes that is characterized by an overload of nutrients. It is often accompanied by algal blooms, low oxygen concentrations, and changes in food web composition and dynamics. In Lake Ontario, persistent eutrophication and undesirable algae are no longer causes of lakewide problems. The elimination of eutrophication problems in Lake Ontario during the 1950s and 1960s is largely due to the success of the binational phosphorus reduction programs and improvements in wastewater treatment plants throughout the entire Great Lakes basin. In the summer of 1993, the average Lake Ontario total phosphorus level was 9.7 ug/L, near the GLWQA objective of 10 ug/L for open lake spring conditions (IJC, 1980 and Thomas et al., 1980).

In the 1950s and 1960s, algal blooms and fish die-offs occurred throughout Lake Erie and Lake Ontario, raising concerns about the environmental impacts of excessively high phosphorus levels. In an attempt to remedy this problem, the GLWQA set a target load of 7,000 metric tonnes of phosphorus per year. To measure the success of the reduction programs, additional targets were set: phosphorus concentration (10 ug/L), chlorophyll a (2.6 ug/L), and water clarity (5.3 m in open waters).

In response to the phosphorus control programs, open lake phosphorus concentrations declined from a peak of about 25 ug/L in 1971 to the 10 ug/L guideline in 1985. By 1991, Lake Ontario phosphorus levels were well below the guideline. In addition, at the time of the Stage 1 beneficial use assessment, water clarity had increased by 20 percent, compared to the early 1980s. Likewise, photosynthesis had declined approximately 18 percent, and late summer zooplankton production had declined by 50 percent. All of these were changes reflecting an overall shift of the lake back towards its original condition of low nutrient levels.

Although significant progress has been made in reducing eutrophication problems in nearshore areas, this is still a concern in local areas. Each of the Lake Ontario AOCs, with the exception of Port Hope and Oswego Harbor, has identified eutrophication as a local impairment. In New York State, Braddock Bay, Irondequoit Bay, Sodus Bay, East Bay, Port Bay, Little Sodus Bay, Chaumont Bay, and Mud Bay are showing signs of eutrophication. Nutrients from agricultural runoff and on-site waste disposal systems (septic systems) are the most frequently identified sources of the problem in these areas. County level environmental planning efforts are providing the lead on controlling these localized eutrophication problems in the U.S.

Growth of the attached green algae *Cladophora* appears to be widespread in the nearshore of western Lake Ontario and along the north shore of the lake. The fouling of shoreline by decaying mats of algae composed largely of *Cladophora*, a common occurrence in the 1960 and 1970s, has been reported in recent years in the St. Catharines, Burlington, Oakville and Mississauga areas. The cause of the apparent resurgence in the abundance of *Cladophora* is unclear, however, an abundance of *Cladophora* has historically been considered as an indicator of nutrient enrichment in the Great Lakes.

In conclusion, it appears that eutrophication is no longer a problem in offshore waters. This is largely due to the success of the binational phosphorus reduction programs and improvements in wastewater treatment plants throughout the entire Great Lakes basin. Although substantial improvements have been made in the nearshore areas, eutrophication may still be a significant issue in some areas.

4.5.5 Restrictions on Drinking Water Consumption, or Taste and Odor Problems

Regular monitoring of the quality of water supplies drawn from Lake Ontario shows that water quality meets or exceeds public health standards for drinking supplies. Open lake surveillance monitoring conducted as part of Canadian and United States research efforts also confirms the high quality of Lake Ontario water.

The largest category of consumer complaints about drinking water worldwide, is taste and odor problems (AWWA, 1987). Changes in the taste of drinking water may indicate possible contamination of the raw water supply, treatment inadequacies, or contamination of the distribution system. Alternatively, microorganisms naturally present in the source water may periodically produce compounds with off taste and flavour. Although there are standards for some parameters that may cause taste and odor problems, such as phenolic compounds, there is considerable variation among consumers as to what is acceptable. Aesthetically acceptable drinking water supplies should not have an offensive taste or smell.

Although there are no drinking water restrictions on the use of Lake Ontario water, many nearshore areas, such as Rochester, the Bay of Quinte, and much of Canadian shores of western Lake Ontario report occasional taste and odor problems. Lake Ontario water suppliers most commonly receive consumer complaints regarding an "earthy" or "musty" taste and odors. Studies conducted by Lake Ontario water suppliers have shown that these problems are related to naturally occurring chemicals, such as geosmin (trans, trans-1,10-dimethyl-9- decalol) and methylisoborneol (MIB), produced by blue-green algae and bacteria. Using chlorine to clear water supply intakes of zebra mussels may also exacerbate the release of these taste and odor-causing chemicals into the water mass. Geosmin and MIB can cause taste and odor problems for sensitive individuals at levels as low as one part per trillion (ppt), well below the detection limits of the analytical equipment currently available to water authorities (2 to 3 ppt). Once identified, taste and odor problems can be alleviated at water treatment plants by the use of powdered activated carbon or potassium permanganate.

Taste and odor problems are more common during algal blooms. Localized eutrophication problems in some nearshore areas may also contribute to taste and odor problems.

During the late summers of 1998 and 1999 a number of water treatment facilities drawing source water from the Canadian shores of western Lake Ontario experienced taste and odor in raw water due to elevated levels of the naturally occurring compound geosmin. The taste and odor episodes of 1998 and 1999 were the impetuous for an ongoing program of research and monitoring into the sources of taste and odor compounds in western Lake Ontario by a consortium of Ontario municipal and government partners known as the Ontario Water Works Research Consortium (see www.owwrc.com). There have not been any severe episodes of taste and odor on the Canadian shores of western Lake Ontario since 1999; however, a late summer pulse in geosmin production has been detected annually in western Lake Ontario since 2000. The wide-scale production of geosmin in the surface waters of the lake is thought to be due to the development of a population of the cyanobacteria *Anabaena lemmermanii* in the lake plankton during late summer.

In summary, taste and odor problems are considered to be a locally impaired beneficial use in some areas yet may be of a more wide-spread problem such as the episodes in western Lake Ontario of 1998 and 1999. There is a diversity of potential causes of off taste and odor in lake water. Naturally occurring algae, eutrophic conditions, and zebra mussel controls may all be important contributing factors.

4.5.6 Beach Closings

Beach closings are restricted largely to shorelines near major metropolitan centers or the mouths of streams and rivers. These closings follow storm events when bacteria-rich surface water runoff is flushed into nearshore areas via streams, rivers, and combined sewer overflows (CSOs). In some instances beaches may be closed based on the potential for high bacteria levels to develop following storm and rain events. Beaches are also closed for aesthetic reasons, such as the presence of algal blooms, dead fish, or garbage. Given the localized nature of beach closings and their absence along much of the Lake Ontario shoreline, they are not a considered lakewide problem.

In Ontario, Canada, beaches are closed when bacterial (E. coli) levels exceed 100 organisms/100mL. From 1995 to 2005 closings have continued in heavily urbanized areas in the western part of the basin due to storm events, but are less frequent in the central and eastern regions. Examples of ongoing problems include the beaches of the Bay of Quinte, Toronto, Burlington, Hamilton, Niagara, Pt. Dalhouse, and St. Catherines. Upgrading stormwater controls through the installation of collection tanks so stormwater from CSOs can be treated in Toronto and Hamilton should reduce number, duration and scale of beach closings in these areas.

On the U.S. side, Congress passed the Beaches and Environmental Assessment and Coastal Health (BEACH) Act in 2000 to improve the protection of public health at beaches with stronger beach monitoring programs. The Act establishes uniform criteria for testing, monitoring and notifying public users of coastal recreational waters, and provides funds to support state and local government monitoring and public notification. From 2001-2005, NYS received $1.4 million for monitoring and public notification. In addition, in 2004 USEPA announced a Clean Beaches strategy which includes a Clean Beaches Plan.

There are 19 beaches on Lake Ontario on the U.S. side. One hundred per cent of Lake Ontario beaches have beach monitoring and public notification in place. The beaches are monitored by county health departments, state health department or State Offices of Parks, Recreation and Historic Preservation (OPRHP). In 2005, 12 beaches were not closed at all and 7 beaches had beach closings totaling 68 days of closure. The closures were for reasons including algae, exceedences of the E. coli single sample limit (235/100 ml); poor water clarity and preemptive closure based on rainfall models.

The sampling frequency for E. Coli is determined by location of beach, closeness to stormwater outfalls, possibility of agricultural run-off and other factors. Sampling is done at 14 beaches once a week; at 1 beach 5 times/month; at 3 beaches every 2 weeks and daily at Ontario Beach. Ontario Beach is in a harbor used by both commercial and recreational boating.

NYS Department of Health is planning a workshop with county and state health departments and OPRHP to review conditions resulting in closures and discuss the status of efforts in identifying and eliminating where possible, the sources of contamination and conditions that contribute to the closures. Follow-up will include monitoring the implementation of mitigation efforts to determine effectiveness.

NYS Department of Health will also analyze beach samples using a rapid test methodology which will provide results in a few hours. The present standard method takes from 24-72 hrs. for a result. If this new method proves valid it will be a tremendous help in the beach closing and re-opening decision making process.

4.5.7 Degradation of Aesthetics

At the time of the Stage 1 beneficial use assessment, there were no aesthetic problems in the open waters of Lake Ontario. This can be attributed to the elimination of widespread eutrophication problems and the restoration of water clarity. However, some Lake Ontario AOCs have identified this impairment. Evaluating aesthetic problems is subjective, often based on individual value judgments. Localized aesthetic problems along Lake Ontario shorelines include algal blooms, dead fish, debris, odor, silty water, improper disposal of boat sewage wastes, and litter problems at parks and scenic highway stops.

On the U.S. side, the Rochester AOC has listed silt, odors related to alewife dieoffs, and decaying algae as aesthetic problems. A water quality survey conducted at the Oswego Harbor AOC around the time of the Stage 1 assessment indicated that this beneficial use was not impaired.

On the Canadian side, the Toronto and Region RAP listed debris and litter, turbidity in the vicinity of tributary mouths and landfilling operations, and weed growth along shorelines as aesthetic problems. In addition, the Royal Commission for Toronto's Waterfront noted the continued loss of Toronto area historical buildings and landscapes and the lack of adequate public access to the lake as aesthetic concerns. The Bay of Quinte RAP identified algal blooms as the primary cause of aesthetic concerns. Major causes of aesthetic impairment in Hamilton Harbour included oil sheens, objectionable turbidity, floating scum, debris, putrid matter, and reduced water clarity in shallow areas.

4.5.8 Degradation of Zooplankton

After the 1997 review, the LaMP Partners agreed that degradation of zooplankton populations was not a lakewide impairment but due to recent changes in the lake described below this BUI is currently being reviewed. The structure and population levels of zooplankton communities are strongly controlled by phytoplankton levels and by the size and distribution of prey fish that feed on them (such as alewife and smelt). Prey fish may have been the most important controlling factor in the 1980s and early 1990s when their populations were much higher than current levels. Declining nutrient levels also played a role. Although the total zooplankton biomass decreased significantly between 1981 and 1987 as nutrient levels fell, the composition of the zooplankton community changed very little in the main lake.

The transport of exotic zooplankton by oceangoing freighters to the Great Lakes remains an on-going threat to Lake Ontario. *Bythotrephes longimanus* (the spiny water flea) was discovered in Lake Ontario in 1982, followed by the zebra mussel in 1989. A decade later in 1998, *Cercopagis pengoi* (also known as the fishhook flea, a zooplankton native to the Ponto-Caspian region of Europe) was discovered in Lake Ontario. Both *Bythotrephes* and *Cercopagis* are predatory cladocerans that feed on smaller native zooplankton. *Bythotrephes* is generally very rare in the lake; however, *Cercopagis* populations develop each summer throughout the surface waters of the lake. The potential impact that these predatory zooplankton will have on Lake Ontario zooplankton communities is not well understood at this time. In addition, it is anticipated that reductions in phytoplankton densities due to zebra and quagga mussel filtering may result in smaller zooplankton populations, particularly in nearshore regions.

Research has provided a better understanding of seasonal changes in zooplankton populations in nearshore, offshore and embayments. Studies carried out around the time of the 2002 BUI assessment in U.S. waters of Lake Ontario indicated that embayments are very productive habitats compared to nearshore and offshore areas. Embayment phosphorus concentrations were nearly twice those in nearshore and three times those in offshore areas. Embayment chlorophyll-a and zooplankton density were higher than both nearshore and offshore habitats. This suggests that embayments may be an important source of food for developing fish.

4.5.9 Added Costs to Agriculture or Industry

This is not a lakewide impairment as Lake Ontario waters do not require any additional treatment costs prior to agricultural or industrial use. The Rochester Embayment AOC was the only Lake Ontario AOC to identify this impairment, based on the additional maintenance costs associated with the physical removal of zebra mussels from water intake pipes.

Many industries and municipalities adjacent to Lake Ontario are experiencing zebra mussel infestation in their water intakes. The main treatment for this problem is to use various chlorine compounds, together with other chemicals such as calcium permanganate, to kill the mussels -- an ongoing maintenance cost.

4.6 Actions and Progress

During the period between the Stage 1 report and this update (1998-2005), no BUIs were delisted and one, degradation of fish populations was added, even though contaminants in fish and wildlife continued to decline. In summary, contaminant levels declined in bald eagles, colonial waterbirds, mink, otter and snapping turtles, and healthy populations of these animals exist around much of Lake Ontario where habitat is suitable. The exception is in the Golden Triangle area where contaminant issues still exist for mink and snapping turtles. For most species, physical habitat quality and loss are greater concerns now, however, disease issues like botulism may also play an important negative role for fish and wildlife. In 2005, the fish population BUI was deemed impaired due mainly to the impacts of non-native species.

Research into the re-introduction of Atlantic salmon, deep water ciscos as well as food quality issues including thiamin deficiency are key action items currently underway that directly address the impaired fish population BUI. Habitat and phytoplankton (nearshore) are deemed impaired mainly due to the impacts of non-native species. Several projects on lower foodweb and benthos status have been completed or are continuing to assess the impacts of these non-native species on the near and offshore ecosystems. The LaMP directly participated in the Lake Ontario Lower Aquatic Foodweb Assessment project (LOLA) and results of this project should be made public in 2006. The zooplankton BUI is currently listed as not impaired and is under review by the LaMP member agencies.

The Lake Ontario LaMP also participated in the International Joint Commissions water level regulation planning exercise for St. Lawrence River and Lake Ontario. LaMP members sat on the Environmental Technical Working Group and the Fish Sub-Committee and also the STELLA simulations Model Evaluation group. In 2005, the LaMP management committee commented on the 3 plans presented to them (see Section 10.2.3).

In 2003, the Lake Ontario LaMP participated in the Lake Ontario Committee Annual Meeting and did so again in March 2006. The 2003 meeting was particularly important because the LOC presented its State of the Lake Report that year and relied heavily on the LaMP member agencies to contribute information about their agencies areas of monitoring and research. This information provided the basis for SOLEC later in 2004 and was key in re-assessing the fish populations BUI in this report. The State of the Lake Report was submitted for publication by the GLFC and will be used by the LOC to create the next Fish Community Objectives as well as Environmental Objectives for Lake Ontario. The Lake Ontario LaMP will also participate in the development of both of these objectives.

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